King County

Historic and Current Status of Kokanee in the Lake Washington Basin

- DISCUSSION DRAFT -

March 13, 2000

King County welcomes comments or suggestions on this draft. Comments are due to King County by 5:00 p.m., Friday, June 14, 2000, and should be sent to:

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EXECUTIVE SUMMARY

The Lake Washington Basin is home to two forms of the salmonid *Oncorhynchus* nerka: sockeye salmon, an anadromous form, and kokanee, a form which resides in freshwater for its entire lifetime. The Lake Washington kokanee population comprises two races of fish: the early-run race and the late-run race. A number of key characteristics, including morphological traits, spawning timing, and unique genetic traits, indicate that the early-run race of kokanee present in Issaquah Creek is native to the Lake Sammamish drainage. Based upon existing data, this appears to be the only remaining population of native kokanee in the Lake Washington Basin, although remnant populations of native kokanee may be present in other tributaries of the Sammamish River / Lake Sammamish drainage. These characteristics, in combination, suggest that the early-run race of kokanee in Issaquah Creek is a unique population of *O. nerka*, as other kokanee stocks in the drainage do not possess any of these same traits. This conclusion is supported by historic evidence, which indicates that native early-run kokanee were both abundant and widespread in the Sammamish River / Lake Sammamish drainage prior to the end of the 19^{th} century.

Based upon the review of existing data, the population of early-run kokanee, including those in Issaquah Creek, collapsed in the mid-1980s and continues to decline to very low levels. This collapse was probably caused by a combination of several factors, including:

- the outplanting of 3.5 million hatchery fish from Lake Whatcom into Lake Sammamish from 1976 through 1979, which likely resulted in increased competitive pressures to native juvenile kokanee rearing in Lake Sammamish;
- severe flooding in December 1975 and subsequent low returns of 1979 and 1983 spawner year-classes (Pfeifer 1995);
- the blockage and eradication of spawning kokanee at the Issaquah Hatchery;
- habitat destruction and migration blockages in spawning streams caused by urban development; and
- shifts in the zooplankton food base of kokanee in Lake Sammamish caused by urbanization and eutrophication control measures.

Recent year-class escapement estimates for the early-run Issaquah Creek population are very low in absolute and relative numbers, with the 1998 year-class estimate of escapement being zero and the 1999 estimate at four fish.

An improvement in the knowledge base regarding Issaquah Creek early-run kokanee, and Lake Washington Basin kokanee in general, will be critical to the long term sustainability of native kokanee populations in the basin. Specific information needs have been identified, including:

- Undertake further analysis into genetic origin and differentiation, limiting factors, and food sources and dependencies
- Document the abundance, distribution, periodicity, and physico-chemical relationships of zooplankton in Lake Sammamish;
- Estimate the abundance of predators, and assess the effects of predation on kokanee;
- Determine the abundance of sockeye and kokanee using trawl and hydroacoustic techniques;
- Evaluate the impacts of sockeye salmon (e.g., competition for shared food resources) on kokanee populations;
- Determine the distribution and movements of kokanee relative to limnological and physical habitat conditions;
- Monitor fry survival of kokanee;
- Assess spawning and rearing conditions for kokanee in Lake Sammamish tributaries, including Issaquah Creek;
- Evaluate the feasibility of supplementation programs to improve native kokanee stocks, including culturing fish at the Issaquah Hatchery.
- Identify, analyze and undertake peer review of options for conservation actions to be taken in the near and long term

1.0 Introduction

Native kokanee (*Oncorhynchus nerka*) populations have undergone a severe decline in abundance and distribution in the Lake Washington Basin (WRIA 8) since the early part of the 20th century. Kokanee is the freshwater resident form of sockeye salmon, and was originally the dominant and most widespread form of this species in the Lake Washington Basin prior to the planting of large numbers of non-native sockeye salmon by the Washington Department of Fisheries (WDF) starting in the mid-1930s (Gustafson et al. 1997). Kokanee were historically widespread throughout Lake Washington and its tributaries (Bean 1891), and were considered to be a valuable sportfishing species (Anon. 1905). However, kokanee in the Lake Washington Basin are currently limited in distribution to the Sammamish River and its tributaries, the Lake Sammamish drainage, and the Cedar River drainage (Gustafson et al. 1997).

The concern for native kokanee populations in this basin was first documented in the early 1970s, when biologists with the Washington Department of Game (WDG) concluded that native kokanee in Big Bear Creek had become extinct due to introductions of large numbers of non-native hatchery fish (Fletcher 1973a). Declining catch-rates of kokanee by sport fishing in the Lake Washington Basin caused concern within the Washington Department of Wildlife (WDW) during the mid 1970s (Pfeifer 1995). This concern increased through the 1980s, when a comprehensive creel census of kokanee in the basin conducted by WDW found "very low catch rates in Lake Sammamish, and practically no fishery for kokanee in Lake Washington" (Pfeifer 1992). In particular, WDW was concerned about the decline in abundance of early-run kokanee in Issaquah Creek, which was then thought to be the only remaining stock of native-origin fish in the Lake Washington Basin (Pfeifer 1995). The total annual escapement of early-run kokanee in Issaquah Creek was reported to vary between one thousand and three thousand spawners during the early 1970s (Berggren 1974).

The population of early-run kokanee spawners in Issaquah Creek apparently collapsed during the early to mid 1980s. The estimated escapement of early-run kokanee in Issaquah Creek ranged between approximately 400 and 1000 individuals from 1980 through 1983 (Pfeifer 1992). Only 10 early-run spawners, however, were observed in Issaquah Creek during 1983. The low number of spawners observed during 1983 may have resulted from severe flooding that occurred in this drainage during December 1975 (Pfeifer 1992), as the 1975 flood may have killed eggs or fry that would have been the ancestor stock for the 1979 and 1983 spawners, given a four year cycle.

Concern for kokanee in the Lake Sammamish drainage was elevated further based upon the results of spawning surveys for early-run fish conducted by the WDW during 1990 (Pfeifer 1992), and by King County staff and volunteers from 1992 through 1998 (Ostergaard 1998c). In 1994, as part of the implementation of the East Lake Sammamish Basin and Nonpoint Action Plan, King County Department of Natural Resources (KCDNR) implemented a five-year study to evaluate the population status and distribution of kokanee in the East Lake Sammamish drainage. The results of those surveys estimated the population of native early-run kokanee in Issaquah Creek at less than 100 fish and the total population of kokanee, including stocks of both non-native and native origin, to be less than 1,000 fish in the Lake Sammamish drainage (Ostergaard et al. 1995; Ostergaard 1996, 1998a, 1998b). The observed distribution of kokanee appears to have been reduced to twelve of the streams historically known to support them. These population trends suggest a “very real and immediate threat to kokanee survival in the Lake Sammamish drainage basin” (Sims 1998).

In response to the decline of kokanee in the Lake Washington Basin and the need for any information in which to ground potentially necessary conservation actions to prevent the disappearance of native kokanee, KCDNR requested a report summarizing the historic and current status of remaining kokanee stocks within the basin. This report was prepared in response to that request. The report was prepared by acquiring and reviewing historical documentation and contemporary research reports on kokanee in the Lake Washington and Lake Sammamish drainages. In addition, interviews were conducted with local residents having knowledge of the distribution and relative abundance of kokanee in these systems. These interviews were conducted and documented by Historical Research Associates (HRA), Seattle, Washington. This report: (1) summarizes the historical and current population status of kokanee in the Lake Washington Basin and Sammamish River / Lake Sammamish drainage; (2) identifies and discusses factors likely to be responsible for the decline of kokanee; and (3) and identifies additional information necessary for the near and long term identification and implementation of conservation actions that would benefit native kokanee.

2.0 *Oncorhynchus nerka* Populations in the Lake Washington Watershed (WRIA 8)

2.1 Life History Forms

The salmon species *O. nerka* is present as two different life history forms in the Lake Washington Basin: sockeye salmon and kokanee. Sockeye salmon, the anadromous form, is presently the most abundant life history form of *O. nerka* in the basin. Kokanee, the resident or "land-locked" form of *O. nerka*, was historically the most abundant life history form in this system, but is now present in small numbers compared to sockeye salmon.

2.1.1 Sockeye Salmon

Sockeye salmon is the anadromous form of *O. nerka*, migrating from the ocean via Puget Sound and the Lake Washington Ship Canal into Lake Washington. Sockeye salmon migrate into the Lake Washington Basin from mid-June through the end of August (WDFW et al. 1994). These fish spawn in tributaries and lakeshore areas of Lake Washington generally from mid-September through late-November, although sockeye in the Cedar River will spawn through mid-January. After emerging from spawning gravels situated along lakeshore areas or in tributaries, sockeye salmon usually migrate to and rear in lakes for one to three years prior to migrating to the ocean (Gustafson et al. 1997). Adult sockeye salmon return to their natal streams and lakes after spending between one and four years in the ocean.

The largest sockeye salmon stock in the Lake Washington Basin is located in the Cedar River, with annual spawner escapement varying from 76,000 to 410,000 fish from 1967 through 1991 (WDWF et al. 1994). Sockeye salmon also spawn in Sammamish River / Lake Sammamish tributaries, including Big Bear Creek and Issaquah Creek. The annual escapement of sockeye spawners in the Sammamish River drainage ranged from 9,700 to 29,700 individuals from 1982 through 1991 (WDFW et al. 1994). A third stock of sockeye salmon is comprised of Lake Washington beach spawning fish, which had an estimated annual escapement varying from 54 to 1,032 fish from 1976 through 1991.

Sockeye salmon are the most abundant life history form of *O. nerka* in the Lake Washington Basin, a result of extensive outplantings of non-native hatchery derived fry and fingerlings since the 1930s (Hendry 1995). Sockeye salmon were thought to be present in small numbers in the Lake Washington system at the end of the 19th century according to some historical reports, while other historical documentation suggests that sockeye salmon were not present at all in this system prior to their introduction in 1935 (Gustafson et al. 1997). Lake Washington now possesses the largest population of sockeye salmon in Washington State (WDFW et al. 1994). The success of sockeye salmon in this system may be due to a number of factors, including the construction of the Lake Washington Ship Canal in 1916, which provided a shorter migration route between Lake Washington and Puget Sound than the Black River and Duwamish River. Changes in the drainage patterns, water quality, and trophic structure of the lake caused by the modifications to the Cedar River and Lake Washington outlet may also have favored sockeye (Gustafson et al. 1997).

2.1.2 Kokanee

Kokanee is a form of *O. nerka* which spends its entire life in freshwater (i.e., it is non-anadromous). This life form is typically found in land-locked lakes where access to the ocean is difficult or impossible (Gustafson et al. 1997). Kokanee differ from “residual” or “resident” sockeye salmon, since kokanee are derived from freshwater resident forms while the residual sockeye are derived from anadromous forms. Most native kokanee populations are thought to have originated from ancestral sockeye salmon which historically migrated into a lake or river system. However, kokanee are often genetically distinct from sockeye salmon in a given region due to genetic isolation and mutation (Gustafson et al. 1997).

Kokanee historically spawned in tributaries located throughout the Lake Washington Basin (Bean 1891; Garlick 1946) (Figure 2.1), but are now found only in the Sammamish River and its tributaries, the Lake Sammamish drainage (Pfeifer 1995; Gustafson et al. 1997; Ostergaard 1998a), and in Walsh Lake (Cedar River drainage) (SPU 1998) (Figure 2.2). During spawning surveys conducted by KCDNR staff and volunteers during the 1990s, kokanee were observed in the mainstem Sammamish River, in tributaries to this river including Swamp, Little Bear, Big

Figure 2.1 Historic distribution of kokanee in the Lake Washington Basin (source: Bean 1991; Garlick 1946; Evermann and Meek 1898; L. Carlson, pers. Com.; B. Bergsma, pers. Com; Ostergaard 1995).

Figure 2.2 Current distribution of kokanee in the Lake Washington Basin (source: Ostergaard, unpublished data; SPU 1998).

Bear, and Cottage creeks, and in tributaries to Lake Sammamish including Issaquah, Tibbetts, Lewis, Pine Lake, Laughing Jacobs, and Ebright creeks (Ostergaard 1998a).

Kokanee in the Sammamish River / Lake Sammamish drainage can be separated into two races based on spawning time:

- *Early-run kokanee*, which spawn during the late summer (August through September);

- *Late-run kokanee*, which spawn during the fall and early winter (October through December).

The early-run race has only been observed in Issaquah Creek, with occasional fish observed in Lewis and Tibbetts creeks during spawning surveys conducted in 1996 (Ostergaard 1998a). It is possible that small numbers of early-run kokanee spawn in other tributaries to Lake Sammamish and Lake Washington. During spawning surveys conducted in 1980, entry of early-run kokanee into Issaquah Creek was observed to commence during the first week of August. The abundance of early-run spawners peaked during the last week of August, and spawning was probably completed by mid-September (Berggren 1974; Pfeifer 1980). Spawner surveys conducted in Issaquah Creek in 1996 found the run timing of early-run kokanee to extend from August 14 through September 16 (Ostergaard 1998a).

Of the remaining kokanee populations in the Sammamish River / Lake Sammamish drainage, only the early-run race is believed to be native in origin (Pfeifer 1992; Pfeifer 1995; Ostergaard et al. 1995). In the early 1900s, according to a Snoqualmie Tribal historian, kokanee spawned in August and September in at least nine Lake Sammamish tributaries (Ostergaard et al. 1995). Historic information suggests that early-run kokanee were also present in the Cedar River (Pautzke, undated). Because of their probable native status and declining population trends, early-run kokanee in Lake Sammamish have been identified as that warranting the greatest priority for future protection, management, and recovery by the Washington Department of Fish and Wildlife (Pfeifer 1995; 1999).

The late-run race of kokanee is present in the Sammamish River and its tributaries, and in Lake Sammamish tributaries including Issaquah Creek (Pfeifer 1995; Gustafson et al. 1997; Ostergaard 1998a). In 1996, spawning by the late-run race was observed to extend from November 2nd through January 4th in most Lake Sammamish tributaries (Ostergaard 1998a). However, the spawning period of kokanee in several Sammamish River tributaries, including Little Bear and Big Bear Creek, has been observed to occur earlier, commencing in mid-September (Ostergaard 1998a).

Historical evidence suggests that the early-run and late-run races of kokanee were both native to the Lake Washington Basin (Gustafson et al. 1997). Unfortunately, native populations of late-run fish may have become extinct due to the outplanting of large numbers of hatchery-produced kokanee fry and fingerlings from Lake Whatcom into the Lake Washington and Lake Sammamish drainages by WDG. The origin population of the non-native kokanee planted into these drainages have a spawning timing similar to the presumed timing of native late-run fish (Ostergaard et al. 1995; Pfeifer 1995). This overlap of spawning timing may have resulted in the widespread genetic introgression of the native late-run race with non-native Lake Whatcom kokanee, causing the decline and possible extinction of the native late-run race. Sockeye salmon also have a spawning time similar to late-run kokanee, and may interbreed with kokanee in Big Bear Creek, Issaquah Creek (Pfeifer 1992), Laughing Jacobs Creek, and Lewis Creek (Ostergaard et al. 1995), furthering the potential for genetic introgression.

2.2 Historical Condition of Kokanee Populations in the Lake Washington Basin

Historical records document that native kokanee were both abundant and well distributed in the Lake Washington Basin prior to the turn of the 20th century. Kokanee were originally identified as Kennerly's trout (*Salmo kennerlyi* Suckley) in 1861 (Suckley 1861), and were referred to by the common name "redfish" (Anonymous 1880). This species was later determined to be the nonanadromous form of sockeye salmon, *O. nerka* (Jordon and Evermann 1902). Kokanee were historically referred to as "silver trout" by Washington Department of Game (WDG) reports, as "redfish" by local residents, and sometimes as "graylings" by sport fishermen in Lake Washington.

2.2.1 Late 1800s

Kokanee were present in fish collections of Lake Washington conducted by the University of Washington during November 1888 and October 1889 (Bean 1891). Kokanee were described as being "common" in the Lake Washington system, in contrast to sockeye salmon which were reported to be uncommon south of the Nooksack River. Interviews with local Indians during this period confirmed that these fish were present in Lake Washington during their entire lives, migrating to tributaries only to spawn. A "great number" of kokanee were observed running up "Bear's River" (Big Bear Creek) to spawn in mid-September during the 1880s (Bean 1891). "Redfish" were observed in tributaries of Union Bay during early fall in the late 1800s (Evermann and Meek 1898). The abundance of kokanee during this period was reported to be greatest in Squak Slough (presently the Sammamish River channel), and tributaries located at the northern end of Lake Washington. Tributary spawning within this region of the lake was reported to have occurred in late October and early November.

Kokanee were also recorded in the Lake Washington basin at the end of the 19th century (Hammond 1886; Seale 1895; Evermann and Meek 1898; Rathbun 1900; Evermann and Goldsborough 1907; Cobb 1911). The "little redfish" were also documented to occur in Lake Sammamish during this period (Jordon and Evermann 1902). Unfortunately, the absolute abundance of this species was not well defined by the biological surveys conducted during this time. Evermann and Meek (1898) relied heavily on information supplied by local residents to describe the distribution, habits, and abundance of kokanee in the basin. According to locals, kokanee moved into shallow areas of Lake Washington during late October and parts of November, presumably to spawn (Evermann and Meek 1898). They also learned that kokanee were plentiful in the Sammamish River and in creeks at the "head" of Lake Sammamish (including Issaquah Creek) in November, and that spawning was believed to occur from the latter part of October to mid-November. Evermann and Meek (1898) failed to observe or collect any kokanee in the Sammamish River to substantiate these reports, although high water levels in the river probably hindered sampling efficiency.

Evermann and Meek (1898) collected only a few kokanee in Lake Washington during seining and gillnet sampling in November and December of 1896. No kokanee were captured in Lake Sammamish during gillnet, trolling, and surface townet sampling from 31 December 1896 to 6 January 1897. Evermann and Meek concluded that these limited collections were insufficient to develop an opinion as to the habits of this species in the two lakes.

Kokanee were described as an economic species in Lake Sammamish during the late 1800s (Evermann and Meek 1898). A regional sporting journal reported that kokanee, referred to as "grayling" and "redfish" by locals, were caught for sport fishing in Lake Washington as well, with "thousands" of fish observed traveling up streams to their spawning grounds during this period (Anon. 1905). This journal reported a "famous fishing ground" in Lake Washington north of Madison Park, as well as near the outlet into the Black River (presently the outlet of the Cedar River).

Kokanee were an important subsistence species to Native Americans during this period, and were harvested in large numbers in tributaries of northern Lake Washington (Bean 1891; Evermann and Meek 1898). Frank Ebright, who purchased property adjacent to Ebright Creek in 1907, witnessed Indians trapping kokanee near the mouth of this stream and drying them on racks in nearby fields during the late 1800s (Kathryn Ebright, pers. comm.). Snoqualmie Tribal historians reported that early-run kokanee were abundant enough in Lake Sammamish tributaries to allow for harvest (pers. comm. as cited in Pfeifer 1992).

2.2.2 Early 1900s to 1930s

Kokanee, referred to as "silver trout" in this instance, were documented during biological surveys conducted by the WDG during 1919 and 1920 in the Lake Sammamish drainage (Smith 1921). These fish were reported to have an average length of 8.3 inches at maturity. Kokanee were observed in Ebright Creek by local residents during the 1920s and 1930s (Kathryn Ebright, pers. comm.). Families living along Ebright Creek used fish as fertilizer for their vegetable gardens. Kokanee were observed in Juanita Creek in "large numbers" by local residents during the late 1920s and early 1930s. These fish were observed in the tributaries mainly during September and October. A long-time resident of Juanita Creek reported that kokanee were not captured for sport, but were sometimes used "to feed the cats" (Elaine McKenna, pers. comm.). Kokanee spawning was documented in the Sammamish River during late October in 1920 (Smith 1921).

More knowledge on the distribution and habits of kokanee in Lake Washington was gained in the early 1930s through the work of DeLacy (1931) and Schultz and Students (1935). DeLacy (1931) recorded observations of spawning kokanee in Swamp Creek in October of 1931. Schultz and Students (1935) observed the habits of adult kokanee in Swamp Creek from August to December 1933 and found most spawning occurred in October and November. WDG recorded passing over 60 adult kokanee at a trap located on Swamp Creek in September 1938 (WDG unpublished data). The lower section of Swamp Creek was considered to be the "usual spawning grounds" of kokanee (silver trout) in this stream (Donaldson 1939). Kokanee were reported to be abundant in Rutherford and Union creeks (the latter formerly a direct surface tributary to Union Bay) during the 1930s by a long-time resident. Large numbers of kokanee were also reported to use the Evans Creek system during this period (Leonard Carlson, pers. comm.).

Kokanee were reported to be abundant in the Lake Sammamish drainage, including Lewis and Issaquah creeks, during the 1920s and 1930s. Kokanee in Lewis Creek were used as food by families during the depression, with "gunny sacks full of kokanee" taken and much appreciated when money was scarce (Bill Bergsma, pers. comm.). Royal and Seymour (1940) stated that kokanee runs were present in Lake Washington and Lake Sammamish, with spawning runs of "native fish" present in Big Bear Creek, Issaquah Creek, and the Cedar River.

2.2.3 1940s and 1950s

The earliest qualitative account of relative kokanee abundance in the Lake Washington basin was reported in a WDG file report in 1946. Kokanee run sizes in Lake Washington and Sammamish River tributaries ranged from "none" to “very excellent” during surveys on November 8 and 9, 1946 (Table 2.1).

Table 2.1 Qualitative estimates of kokanee run sizes in several Lake Washington Basin tributaries on November 8 and 9, 1946 (source: Garlick 1946).

STREAM	KOKANEE RUN SIZE
May Creek	“Poor”
Coal Creek	“Excellent”
Mercer Slough	“Poor”
Juanita Creek	“Fair”
Little Bear Creek	“Fair”
North Creek	“Very excellent”
Swamp Creek	“Good”
McAleer Creek	“Fair”
Thornton Creek	“None”

The run of kokanee in Swamp Creek was regarded as “good but not outstanding” during spawning surveys conducted in 1946 (Robert Burgner, pers. comm.). Kokanee were also present in the Cedar River during the 1940s (Robert Burgner, pers. comm.). The Cedar River was described as possessing an early-summer (i.e., August) kokanee run during this period (Pautzke, undated).

Big Bear Creek was considered to support the most important run of kokanee in the Lake Washington Basin during the 1940s (USFWS 1950). The WDG obtained as many as 14 million kokanee eggs from Big Bear Creek during this period, from a rack located above the confluence with Evans Creek (WDG undated; USFWS 1950). This egg-taking station was established as a backup to the state’s only “dependable” kokanee source at Lake Whatcom, and was used primarily for kokanee stock supplementation for sport-fishing in the Lake Washington Basin. Based upon the average number of eggs obtained and the sex ratio of kokanee (50:50), the run size of spawners in Big Bear Creek is estimated to have ranged from 6,000 to more than 30,000 fish during this period. Big Bear Creek kokanee populations during the 1940s apparently fluctuated widely from year to year, as the annual number of eggs taken at the Big Bear Creek trap varied from "very small to a bumper crop" (Johansen 1951). Little Bear Creek was reported to possess a "few" kokanee (silver trout) during the 1940s (Garlick 1946). A small number of kokanee were also observed to spawn in the Sammamish River during this period.

A semi-quantitative description of relative kokanee abundance in the basin was produced in the 1950s before the Sammamish River was modified for flood control (WDF, undated). The report to the U.S. Army Corps of Engineers described the annual kokanee run in four streams as follows: North Creek had "several thousand" kokanee; Little Bear Creek contained a "few" kokanee; Big Bear Creek had a "large magnitude" of kokanee; and Issaquah Creek contained a "small run" of kokanee (WDG, undated).

2.2.4 1960s and 1970s

Anecdotal and semi-quantitative information describing kokanee abundance in the Sammamish River / Lake Sammamish drainage is available from the period between 1960 and 1979, along with a single weir count estimate obtained in Issaquah Creek in 1973 (Pfeifer 1995). Kokanee were apparently abundant in Issaquah Creek during the early 1960s, as anglers could easily catch their limit of 20 fish (Bill Bergsma, pers. comm.). Sport fishing for kokanee was a "big thing" in Lake Sammamish tributaries during this period, with "people coming from all over the county to fish here". Good fishing locations for kokanee included the mouth of Issaquah Creek, the mouth of Tibbetts Creek, and the area around Vasa Park (Bill Bergsma, local resident, pers. comm. dated Sept. 14, 1999). Kokanee were considered to be "common" in Juanita Creek in the late 1960s (Brunson 1969).

The abundance of kokanee spawners returning to Issaquah Creek significantly declined during the 1970s (Pfeifer 1980). The abundance of early-run kokanee spawners in Issaquah Creek was estimated to vary between 1,000 and 3,000 fish for the years 1971 and 1972 based upon anecdotal information (Berggren 1974). Based upon weir counts conducted in 1973 there were an estimated 1,000 early-run kokanee spawners in Issaquah Creek (Berggren 1974); these are the only known quantitative data available during this period (Pfeifer 1995). Kokanee were observed in Ebright Creek following the removal of an artificial barrier during the 1970s (Walter Pereyra, pers. comm.). These fish were reported to enter the stream in early November.

The native Big Bear Creek kokanee population was considered to be extinct by WDG biologists during the early 1970s (Fletcher 1973a). The remaining kokanee stock was thought to be derived from Lake Whatcom fish, which were extensively planted in this stream beginning in the 1930s.

2.3 Genetic Origin

2.3.1 Early-Run Kokanee

Studies of the morphology, spawning timing, and genetics of early-run kokanee indicate that this race is native to the Sammamish River / Lake Sammamish watershed (Seeb and Wishard 1977; Wishard 1980; and Hendry 1995). Based upon observations of coloration and spawning timing at the Issaquah Creek Hatchery, native kokanee in Issaquah Creek were considered distinct from translocated sockeye from the Baker River, as well as from kokanee derived from fry planted in the drainage from Lake Whatcom (Fred Utter, pers. comm.).

Comparisons of Lake Whatcom kokanee with those in Issaquah Creek suggest that the latter also match the “native” morphological profile, being brighter red in color and larger in size than Lake Whatcom fish, which have a “subdued pinkish-brown appearance” and are smaller in size (Fletcher 1973b). Residualized sockeye salmon are also subdued in color compared to kokanee, and are larger in size (Quinn et al. 1998). Early-run kokanee in Issaquah Creek spawn from mid-August through mid-September (Fletcher 1973a; Berggren 1974; Pfeifer 1980), which is considerably earlier than the spawning period of kokanee in Lake Whatcom (i.e., late October through December). The differences in appearance and spawning timing suggest that at least a portion of the kokanee present in Issaquah Creek are genetically distinct from Lake Whatcom kokanee, which further suggests that early-run Issaquah Creek fish are native in origin.

Seeb and Wishard (1977) found that early-run kokanee in Issaquah Creek were genetically distinct from six other *O. nerka* stocks present within the basin and three transplanted stocks, including Lake Whatcom kokanee. Further work by Wishard (1980) substantiated the hypothesis that the early-run kokanee race is biochemically distinguishable from other *O. nerka* races in the basin. Hendry (1995) also determined that the early-run kokanee in Issaquah Creek differed significantly from all sockeye stocks in the basin based upon genetic analysis. Early-run kokanee in Issaquah Creek were found to frequently possess an allele (i.e., particular mutational form of a gene) which has only been detected in native and isolated kokanee populations in Oregon and Idaho (Hendry 1995; Anderson 1998). This allele (*NULL or *500 allele) has never been found in other kokanee stocks in the Sammamish River / Lake Sammamish drainage. The high frequency of this allele in early-run kokanee, and the lack of this gene in other kokanee populations in the region, suggests it arose through mutation within the Lake Sammamish drainage (Hendry 1995). The *NULL (*500) allele was found to be completely absent in Issaquah Creek sockeye, suggesting that anadromous *O. nerka* are not spawning successfully with the early-run kokanee (Hendry 1995). These results support the hypothesis that early-run kokanee are native to the Lake Sammamish drainage (Hendry 1995; Ellestad 1995).

2.3.2 Late-Run Kokanee

Historical records from the late 1800s through 1930s documented kokanee spawning in Lake Washington and Sammamish River tributaries from late-October through December, suggesting that late-run kokanee is also a life history form of kokanee native to this drainage. For example, DeLacy (1931) and Schultz and Students (1935) observed kokanee spawning in Swamp Creek in October and November. Unfortunately for native late-run populations, large numbers of kokanee fry originating from Lake Whatcom were planted in the Sammamish River / Lake Sammamish drainage commencing in the 1930s. A total of 35 million fry and fingerlings were introduced to this drainage, with 3.5 million fry planted in Lake Sammamish during the period extending from 1976 through 1979 (Pfeifer 1995). Because Lake Whatcom kokanee have a spawning period (November through December) similar to the presumed spawning period of native late-run kokanee in the Sammamish River / Lake Sammamish drainage, it is likely that these non-native plantings affected the genetic integrity of remaining native kokanee stocks through a range of direct (e.g., interbreeding) and indirect (e.g., competition) mechanisms. The genetic status of late-run kokanee in this drainage remains unknown, although remaining populations are assumed to be comprised mainly of Lake Whatcom fish (Pfeifer 1995; Ostergaard et al. 1995).

The spawning period of late-run kokanee in some Sammamish River tributaries, including Little Bear, Big Bear, and Cottage Lake creeks, is somewhat earlier (i.e., mid-September through mid-October) than the November and December spawning period of Lake Whatcom kokanee (Pfeifer 1992; Ostergaard 1998a). This suggests that these populations may be a remnant of the native late-run kokanee observed by DeLacy (1931) and Schultz and Students (1935). Whether these late-run kokanee are genetically distinct from Lake Whatcom kokanee has yet to be determined.

2.4 Conclusions Regarding the Native Origin of Kokanee

The early-run race of kokanee found in tributaries to Lake Sammamish (including Issaquah Creek, Lewis Creek, and Tibbetts Creek) may be the only remaining native kokanee stock in the Lake Washington Basin. It has been hypothesized that early-run kokanee have been able to maintain their genetic integrity due to the temporal separation in their spawning timing from that of late-run kokanee originating from Lake Whatcom (Pfeifer 1992; Ostergaard et al. 1995). Genetics studies have determined that this stock is unique from other kokanee and sockeye stocks in the Lake Washington basin. Currently, kokanee carcasses are being collected in Issaquah, Laughing Jacobs, Lewis, and Ebright creeks for genetic analysis by the National Marine Fisheries Service (NMFS). Fourteen samples collected in 1998 and nineteen samples collected in 1999 are awaiting analysis by the NMFS.

3.0 Condition of Kokanee Populations in the Lake Washington Watershed

The Washington Department of Fish and Wildlife (WDFW) and KCDNR have monitored adult kokanee escapement in selected streams of the Lake Washington basin since 1980 (Pfeifer 1992; Ostergaard et al. 1995). WDFW intermittently monitored kokanee abundance from 1980 to 1990 on principal tributaries used by this species. Live adults, carcasses, and redds were enumerated via foot surveys in Issaquah Creek in 1980 and 1990, in East Fork Issaquah Creek in 1980, and in Big Bear, Cottage Lake, and Evans creeks in 1983. A fish weir was used to document total adult escapement in Issaquah Creek from 1981 through 1983. Unfortunately, although Big Bear Creek, Cottage Creek, Issaquah Creek, and the East Fork Issaquah Creek were walked on a regular basis to count sockeye spawners, kokanee were not usually counted during these surveys. Pfeifer (1992) summarized the WDW kokanee monitoring efforts from 1980 to 1990. Since 1992, King County staff and volunteers have conducted regular surveys of adult, carcass, and redd counts in streams historically known to contain kokanee to document the current distribution and abundance of this kokanee in the Sammamish River / Lake Sammamish drainage (Table 3.1).

Table 3.1 Sammamish River and Lake Sammamish tributaries surveyed by King County between 1992 and 1997 (source: Ostergaard 1998a).

WATERBODY	YEAR AND SEASON SURVEYED
Issaquah Creek	1992-1997 (late summer); 1992-1996 (fall)
East Fork Issaquah Creek	1992, 1994 (late summer); 1992, 1994-1995 (fall)
Big Bear Creek	1992 (late summer); 1992-1995 (fall)
Cottage Lake Creek	1992-1993 (late summer); 1992-1995 (fall)
Lewis Creek	1994-1997 (fall)
Tibbetts Creek	1996 (late summer); 1994-1997 (fall)
Laughing Jacobs Creek	1996 (late summer); 1993-1997 (fall)
Ebright Creek	1995-1997 (fall)
Pine Lake Creek	1996 (late summer); 1995-1997 (fall)
Swamp Creek	1994-1996 (late summer); 1994-1997 (fall)
Little Bear Creek	1994-1997 (fall)

3.1 Early-Run Kokanee

The WDW cited historic escapement estimates as high as 15,000 for early-run kokanee in Issaquah Creek based upon anecdotal information (Pfeifer 1995). However, these estimates were based upon interviews during the 1980s with Issaquah Creek hatchery workers, and cannot be verified. The total annual escapement of early-run kokanee in Issaquah Creek was reported to vary between one thousand and three thousand spawners during the early 1970s (Berggren 1974). This range of abundance values is probably a more reasonable estimate of the number of kokanee spawners present in Issaquah Creek during the 1970s.

Based upon spawning surveys conducted by the WDW, the estimated annual escapement of early-run kokanee in Issaquah Creek was 692 spawners in 1980, 428 spawners in 1981, and 1,016 spawners in 1982 (Pfeifer 1992)(Figure 3.1). The number of early-run spawners collapsed in 1983, with only 10 spawners observed in Issaquah Creek. The low number of spawners observed during 1983 was attributed to the impacts of severe flooding occurring during December 1975 (Pfeifer 1992). The loss of the 1975 brood-class would have resulted in a low number of spawners in 1979 and subsequently in 1983, assuming that most kokanee spawn as four-year olds. Spawning surveys were not conducted from 1984 through 1989, but were again conducted by WDF in 1990. The estimated escapement of early-run spawners in Issaquah Creek remained a relatively low 90 fish in 1990.

The estimated abundance of early-run kokanee spawners in Issaquah Creek from 1992 through 1998 was very low compared to the estimated escapement of one thousand to three thousand fish during the 1970s, and from 438 to 1,016 spawners from 1980 through 1982. The estimated annual escapement of early-run kokanee in Issaquah Creek has ranged from zero fish (1998) to 39 fish (1994) from 1992 through 1998. The average number of spawners during this period has been 17 fish per year, a dramatic decline from the number of spawners observed in the early 1970s and 1980s. The strong year class identified by WDW in 1982 is no longer distinguishable from all year classes in recent data collected by King County staff and volunteers (Ostergaard 1998c).

The distribution of early-run kokanee currently appears to be restricted to Issaquah Creek, although early-run kokanee have been observed to occasionally stray into Lewis and Tibbetts creeks. This likely represents a reduction in the historic spawning distribution of early-run kokanee. This population has undergone an -5.8 percent trend in annual abundance from 1980 through 1998 (percent annual change estimated from log-linear regression). During the five year period from 1994-1998, the population of early-run kokanee has decline by an average of 9.8 percent per year (i.e., -9.8 percent trend, as estimated from log-linear regression). Thus, the population status of the early-run kokanee race in Issaquah Creek can be considered to be critically low, and appears to be continuing to decline over time. These data indicate that early-run kokanee have been reduced to remnant numbers in the Lake Sammamish drainage, and face an immediate threat to continued survival.

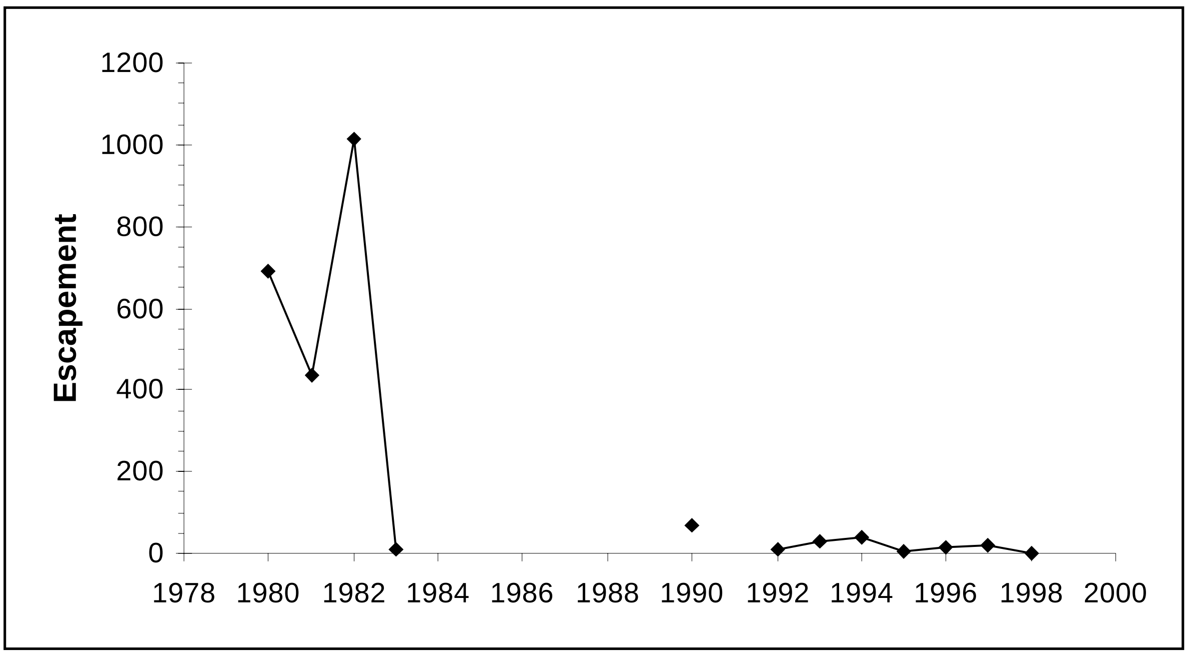

Figure 3.1 Estimated escapement of early-run kokanee spawners in Issaquah Creek, based upon spawner counts from 1978 through 1998 (no data collected from 1984-89; 1992) (source: Pfeifer, 1992; Ostergaard, 1998a).

3.2 Late-Run Kokanee

Late-run kokanee currently spawn in several Lake Sammamish and Sammamish River tributaries, including Big Bear, Cottage Lake, Issaquah, East Fork Issaquah, Lewis, Laughing Jacobs, Ebright, Pine Lake, Swamp, and Little Bear creeks (Ostergaard 1996; Ostergaard 1998a; Ostergaard 1998c). Late-run kokanee using Lake Sammamish tributaries generally spawn in November and December. Data collected since 1992 by King County indicated that late-run kokanee escapement in many Lake Sammamish tributaries exceeded 100 spawners during the period 1993 to 1996, but declined below this value in all surveyed streams in 1997 (Table 3.2).

Table 3.2 Estimated spawner escapement of late-run kokanee in Lake Sammamish tributaries (source: Ostergaard 1998c).

STREAM	1993	1994	1995	1996	1997
Ebright Ck	No surveys	0	11[1]	145	51
Laughing Jacobs Ck	130[1]	136	167	441	63
Lewis Ck	No surveys	182	145	410	2[1]
Pine Lake Ck	No surveys	0	0	15	16

[1]-number of live fish counted, not a calculated escapement estimate

Late-run kokanee using Sammamish River tributaries typically spawn in October and November. Annual estimates of late-run kokanee escapement for Sammamish River tributaries have been less consistent, and as a result, escapement trends since 1992 are more difficult to enumerate. King County and WDFW continue to walk streams to count kokanee spawners, and are ensuring that kokanee are also counted in surveys that focus on anadromous fish species (e.g., chinook, sockeye, and coho salmon).

Identifying historic trends in late-run kokanee escapement for most Lake Sammamish and Sammamish River tributaries is difficult due to a lack of quantitative data collected prior to 1992. There are some limited data, however, that suggest a significant decline has occurred in the late-run kokanee stocks using Sammamish River tributaries. For example, the peak number of spawning kokanee in Swamp Creek (7) reported during a single spot check in 1996 (Ostergaard 1998a) was far fewer than the number of spawners (100) observed by Schultz and Students

(1935) on one riffle located in the same area. Unfortunately, escapement trends in other streams cannot be calculated because of the qualitative (i.e., descriptive) nature of historic data available for Sammamish River tributaries (e.g., Garlick 1946).

Kokanee are also present in Walsh Lake (SPU 1998), which flows into the Cedar River via the Walsh Lake Diversion canal. Kokanee were captured in gill nets during a fish survey conducted in Walsh Lake by Seattle Public Utilities (SPU) in August 1997. The kokanee captured during this survey ranged from 8 to 17 inches in length. Kokanee spawning surveys were conducted by SPU staff during the fall of 1997. Spawning was observed during the first three weeks of October 1997, with a total of 36 adult kokanee observed spawning in tributaries to Walsh Lake (SPU 1998). The genetic origin of kokanee in Walsh Lake is uncertain. Kokanee were not observed during fish surveys conducted in Walsh Lake by the University of Washington in 1977. However, it is possible that kokanee were present but not captured in the gill nets used during the surveys (SPU 1998). Thus, the relationship of kokanee in Walsh Lake with other populations present in the Lake Washington drainage is not yet known. No genetics testing has been conducted to date on kokanee in Walsh Lake. The spawning timing of fish in this system appears to be intermediate between early-run and late-run kokanee present in the Lake Sammamish drainage.

Like early-run kokanee, the status of late-run kokanee in the Sammamish River / Lake Sammamish drainage appears to be depressed compared to the historic abundance of this race. Unfortunately, the status of late-run kokanee population is not definitively known due to the lack of spawner abundance data prior to 1992. This lack of data does not allow for analysis of any historical trends in annual kokanee escapement. However, recent monitoring data suggest that the abundance of late-run kokanee in the Lake Sammamish drainage is considerably higher than early-run kokanee. The estimated annual escapement of late-run kokanee in Lake Sammamish streams averaged 446 spawners per year from 1994 through 1997 (Ostergaard 1998a and c). The actual number of late-run kokanee spawners in the Sammamish River / Lake Sammamish drainage during this period is probably much higher than this value; this number does not included the Sammamish River and its tributaries, which are also used by late-run kokanee spawners. Moreover, spawner surveys in recent years suggest that populations of late-run kokanee may be increasing (exemplified by high number of spawners counted in 1996)(Ostergaard 1998a). For these reasons, some late-run kokanee populations may not be faced with an immediate threat to their continued survival.

4.0 Factors Affecting the Sustainability of Native Kokanee in the Lake Washington Watershed

A number of factors are likely responsible for the historical decline of native kokanee in the Lake Washington drainage. These factors include: (1) hatchery outplanting programs and resulting genetic introgression; (2) widespread habitat loss and degradation; (3) trapping programs conducted by WDF; (4) blocked upstream passage by artificial barriers and low flows; (5) shifts in zooplankton densities and composition in Lake Washington and Lake Sammamish; (6) disease; (7) predation and competition from non-native fish species, including *O. nerka* from other basins; and (8) sport-fishing pressures.

4.1 Hatchery Outplanting Programs

Hatchery outplantings of non-native kokanee may have severely impacted native kokanee populations by allowing interbreeding among non-native and native fish, and therefore genetically “diluting” or replacing native kokanee runs. Genetic introgression (i.e., shift in genetic composition of native fish caused by interbreeding with non-native fish) resulting from introductions of large numbers of kokanee fry originating from outside of the basin may have resulted in the extinction of native kokanee runs in many streams, including Big Bear Creek (Fletcher 1973a). Large numbers of kokanee fry originating from Lake Whatcom stocks were outplanted in this drainage in the 1930s through 1970s. These hatchery releases were thought to have resulted in widespread genetic introgression with native stocks, especially late-run kokanee in Big Bear Creek (Fletcher 1973a). Genetic introgression of native kokanee stocks may also have been caused by the planting of large numbers of sockeye salmon in the drainage, particularly in the Cedar River. Large numbers of kokanee fry originating within the drainage (Big Bear Creek egg-taking station) were also outplanted in the basin during the late 1940s. A total of 3.5 million fry were planted in Lake Sammamish during the period extending from 1976 through 1979 (Pfeifer 1992).

Nearly 87 million kokanee fry of hatchery origin were released throughout the basin from 1919 to 1979 (Pfeifer 1992). The source of approximately half of these was Lake Whatcom in Skagit County. Approximately 41 percent of the total kokanee planted originated from trap and egg-taking stations within the basin. A small percentage of total fry releases were from Lake Stevens and other unknown sources. Only 1.5 percent of the Lake Whatcom fry were released into Lake Washington tributaries (Lyon and May creeks, and the Cedar River). The balance of the Lake Whatcom plantings occurred in Lake Sammamish and Sammamish River tributaries. Approximately 77 percent (nearly 34 million fry) of the total Lake Whatcom plants were released into Big Bear Creek from 1942 to 1969 (Pfeifer 1992). The releases were purposely concentrated into Big Bear Creek to create another dependable source of kokanee eggs for the WDG should the supply at Lake Whatcom suddenly decline (Johansen 1951). It is clear from the apportionment of outplants that Lake Whatcom origin kokanee had a greater chance of spawning with native kokanee in Sammamish River tributaries, particularly Big Bear Creek.

Kokanee were abundant enough in the basin in the first half of this century to support an egg-taking and out-planting program. To collect adults for artificial spawning, traps were installed and operated by King County and the WDG. Adult kokanee were trapped in a number of Lake Washington and Sammamish River tributaries, principally Thornton, McAleer, Swamp, Big Bear, and Juanita creeks (Pfeifer 1992). Progeny from the spawned adults were planted throughout the basin. From 1922 to 1951, the county and state egg-taking program in the Lake Washington basin resulted in the outplanting of nearly 36 million kokanee fry (Pfeifer 1992). Between 2.6 and 5.5 million eggs were obtained from adult kokanee captured at an egg-taking station established on Big Bear Creek from 1946 through 1950 (WDG undated). Fry produced from these eggs obtained during this period were released near the trap site in Big Bear Creek (near the confluence with Evans Creek).

Some kokanee released into the Lake Washington basin originated from unspecified sources. Just over 7 million fry of unknown origin were stocked into the basin from 1917 to 1930 (Pfeifer 1992). A total of 1,450,000 kokanee (silver trout) fry were planted in Lake Sammamish during 1919 from unspecified sources (Darwin 1921). In 1922, a total of 635,000 kokanee (silver trout) fry were planted in Lake Sammamish, 260,000 fry were planted in Lake Washington, and 896,000 fry were planted in Evans Creek (Dibble and Kinney 1923).

The plantings of sockeye salmon in Issaquah Creek, Big Bear Creek, and Cedar River were a concern to some fisheries managers in the 1940s because of the presence of “native” kokanee in these streams (Royal and Seymour 1940). Sockeye fry obtained from the Birdsview Hatchery (Grandy Creek on Skagit River) were planted in Issaquah Creek, Big Bear Creek, and the Cedar River in 1937 (Royal and Seymour 1940). A total of 576,000 sockeye fry were planted in Big Bear Creek, while 1,257,000 were planted in Issaquah Creek and 576,000 in the Cedar River. These plantings produced the most successful results in Issaquah Creek, with an estimated 9,099 adult sockeye returning during the fall of 1940.

Kokanee in the Lake Washington basin are now managed by the WDFW for natural production only, and planting of non-indigenous hatchery fish has not occurred since 1979. As recently as 1982 and 1983, an egg-taking operation on Issaquah Creek resulted in the planting of 54,635 fry into Issaquah Creek to augment the declining early-run population (Pfeifer 1992).

4.2 Habitat Degradation and Loss

The historic degradation and loss of kokanee habitat in the Lake Washington basin has been both widespread and severe. Many of the most important spawning areas of this basin have been lost due to extensive landfilling in nearshore areas, construction of the Lake Washington Ship Canal, lowering of Lake Washington, and the completion of the Sammamish River flood control (channelization) project. Based upon historic records, the most important kokanee spawning areas at the turn of the century likely included Squak Slough (presently the lower Sammamish River), tributaries in northern Lake Washington, tributaries to Union Bay, and the outlet of the Cedar River into the Black River. These areas were either lost or seriously impacted by the construction of the Lake Washington Ship Canal and rerouting of the lower Black and Cedar rivers in 1912, the lowering of Lake Washington in 1916, and by extensive landfilling projects in Union Bay and northern Lake Washington.

Historically, the Sammamish River was a slow, meandering stream bordered by marshlands (Chrzastowki 1983). Lowering of Lake Washington resulted in narrowing and steepening of this broad and low gradient channel; the channel was later dredged, resulting in destruction of the spawning habitat (Ajwani 1956). The former Black River channel was largely filled in for commercial and industrial land (Chrzastowki 1983). Most of the shallow, high quality spawning habitat areas in Union Bay were lost due to the lowering of Lake Washington, wetland draining, and landfill projects which included that for a major solid-waste disposal facility (Montlake Dump). Ravenna Creek, a stream that entered the head of Union Bay and was historically described as a productive kokanee spawning stream, was diverted to city sewers in 1911 (Chrzastowki 1983).

Kokanee have also been impacted by excessive sedimentation caused by watershed development. An example of the problems that can occur was provided by a large kokanee egg kill caused by “extreme” siltation in Juanita Creek in March 1969 (Brunson 1969). Approximately 500,000 eggs planted into a small tributary of this stream were killed by siltation caused by building construction.

As a result of land developments and associated habitat degradation and loss, suitable spawning habitats may now be limited in many streams within the Sammamish River / Lake Sammamish watershed. An example of this problem is found in Issaquah Creek, where kokanee spawning in several sections of this stream was found to be limited to scarce patches of suitably-sized spawning gravels, especially in East Fork Issaquah Creek (Pfeifer 1980).

Severe flooding in December 1975 has been suggested as a likely factor contributing to the collapse of early-run kokanee in the Lake Sammamish drainage during 1983 (Pfeifer 1992).

4.3 Trapping Programs

Native kokanee were trapped and discarded by the WDF at the Issaquah Creek Hatchery in the 1960s and 1970s (Fred Utter, pers. comm.). These fish were not perceived to have sport fishing or commercial value, and were captured and destroyed because they were thought to be a potential carrier of the IHN virus. Hatchery employees feared that kokanee represented a disease threat to chinook and coho salmon, which are the primary species raised at the hatchery. During the 1960s, WDF's fish culturist directed hatchery staff to collect kokanee and other unwanted fish into quarter-acre ponds. When several thousand fish had accumulated, the ponds would be drained and the dead fish hauled to the dump (John Kougan, pers. comm.). Consequently, native kokanee stocks in Issaquah Creek were greatly reduced by the trapping program conducted by the hatchery (Fred Utter, pers. comm.). Kokanee were later found not to be a disease threat to chinook and coho salmon raised in the Issaquah Hatchery.

4.4 Blocked Upstream Passage

Historical accounts described earlier in this report provide evidence that kokanee were intentionally blocked from entering some tributaries by local residents. Passage of kokanee into Ebright Creek was blocked by property owners prior to 1973 because of odor problems caused by the carcasses of spawned-out fish. This barrier was removed in 1973 (Walter Pereyra, pers. comm.). The root of a large cottonwood tree and the remnants of an old fish weir may have blocked the upstream migration of kokanee into this stream during the late 1980s (Walter Pereyra, pers. comm.). Kokanee were often considered a “trash fish” by some local residents, though historic documents provide evidence of extensive use of kokanee for subsistence purposes by Native Americans in Lake Washington, as well as a sport fishery at the turn of the century.

Upstream passage in many tributaries has been hindered or blocked by channel aggradation and widening, by reduced flows during the late summer and early fall, and by improperly designed culverts. These problems are common within tributaries in the Sammamish River / Lake Sammamish watershed due to urbanization. Early-run kokanee may be especially vulnerable to passage barriers, since they typically migrate upstream during August when streamflows are low.

Several sections of Issaquah Creek were considered potential barriers to upstream passage due to shallow depths under low-flow conditions (Pfeifer 1980). A total of 318 kokanee redds were counted in Issaquah Creek during August and September of 1980. Densities of spawners were greatest in the sections of the stream immediately downstream of the Issaquah Creek Hatchery weir. No spawning was observed in the sections of Issaquah Creek just above the weir, even though spawning gravels were found to be present in these sections. The hatchery weir may have concentrated spawners within those sections of the stream immediately below the weir (Pfeifer 1980).

The WDG, concerned over continuing declines in the Issaquah Creek kokanee population, on several occasions requested that the WDF allow kokanee to pass upstream of the Issaquah Creek Hatchery weir (Pfeifer 1980, 1981). The WDG identified the blockage of upstream migration by the weir as a major factor for the decline of kokanee in this stream (Pfeifer 1982). The WDF, re-emphasizing their concern over the IHN virus, continued to block access to areas above to weir to all fish with the exception of some hatchery reared chinook and coho salmon.

4.5 Shifts in Zooplankton Densities and Predation

Kokanee and sockeye salmon feed primarily on zooplankton. The cladoceran *Daphnia* is the preferred food item of kokanee and sockeye fry and juveniles, which are limnetic feeders (Foerster 1968). Changes in the abundance, species composition, size, and vertical distribution of zooplankton, especially *Daphnia*, have been implicated as the primary cause of the declining kokanee abundance in a number of lakes and reservoirs (Foerster 1968; Paragamian and Bowles 1995; Martinez and Wiltzius 1995). *Daphnia* were present in Lake Washington in the 1930s, but were not observed in the lake between 1950 and 1972 (Eggers et al. 1978). The disappearance of this zooplankter from the lake was attributed to trophic changes in the lake (including primary production), and the introduction of the mysid shrimp *Neomysis*. *Daphnia* reappeared in Lake Washington in 1972. However, sockeye salmon in Lake Washington may not be influenced by variations in *Daphnia* abundance as observed in other lakes. Eggers (1982) found that sockeye salmon in Lake Washington show a preference for large noninvasive zooplankters, but that this preference shifts as a consequence of the seasonal availability of large prey types.

More recent research suggests that seasonal food availability may be a more important limiting factor to fish production in Lake Washington and Lake Sammamish. Phytoplankton populations in Lake Washington have been found to have “noisy seasonal cycles”, while those in Lake Sammamish have been found to be highly stochastic (i.e., random)(She 1998). Wide fluctuations in food availability on a seasonal and year-to-year basis may limit the production of planktivorous fish such as kokanee.

4.6 Disease

The effects of disease on kokanee populations in the Sammamish River / Lake Sammamish watershed are largely unknown. One documented incident of disease in kokanee populations occurred in 1940, when a large number of unspawned sockeye salmon died in Issaquah Creek. These deaths likely resulted from fungus growth on the head and eyes of these fish (Royal and Seymour 1940). Fungus was later observed in the kokanee salmon run in Issaquah Creek. Sockeye salmon spawners were very abundant in 1940, a result of the “successful” planting of 1,257,000 sockeye fry and fingerlings obtained from the Birdsview Hatchery (Baker Lake) in 1937. It is possible that the large number of sockeye salmon returning to this stream resulted in the outbreak of this disease, and that it “carried over” to the fall kokanee run.

4.7 Predation and Competition from Non-Native Fishes

Predation by northern pikeminnow is thought to have a significant impact on the abundance of juvenile sockeye salmon - and presumably kokanee - in Lake Washington (Eggers et al. 1978). Impacts of predation of predators such as small mouth bass, which are abundant in Lake Sammamish, on kokanee fry and juveniles has not been studied. However, predators may have a significant impact on the production of kokanee in the Sammamish River / Lake Sammamish watershed.

The successful introduction of hatchery-origin sockeye salmon into the Lake Washington and Lake Sammamish basins likely resulted in increased competition for native juvenile kokanee, which forage on the same items as juvenile sockeye salmon. The introduction of 3.5 million hatchery-origin (Lake Whatcom) fry into Lake Sammamish in 1976 through 1979 may have partially contributed to the collapse of the Issaquah Creek early-run kokanee population in 1983.

4.8 Sportfishing Pressure

As mentioned earlier, kokanee were historically a popular species for sportfishing in the Lake Washington and Lake Sammamish drainages. Sportfishing pressure may have contributed to the decline of this species since the 1960s. Current sportfishing pressure is likely to be low on this species, since it is no longer abundant and is not a popular fishery.

5.0 Further Information Needs

Given the apparently grave condition of the Issaquah Creek early-run kokanee population, timely attention to specific options for actions that would contribute to the sustainability of native kokanee is necessary. During the course of this literature review several options for such action were uncovered, including broodstock programs involving native and non-native stocks, lake fertilization, construction of spawning channels, barrier removal and stream habitat improvements. Although over the long term the emphasis for conservation actions is better directed toward addressing causal (i.e., ecosystem level) factors for kokanee decline, it may be the case that the primary symptom of decline - low spawner numbers - must be addressed first to raise the population to a level where addressing causal factors will in fact contribute to population sustainability. Weighing the immediacy of the need for action with the need to explore the range of options fully, local technical staff - from jurisdictions, agencies, tribes, non-governmental organizations, and other stakeholder groups - should undertake a collaborative, comprehensive effort to identify and analyze options for actions. This analysis should be reviewed by a peer review body comprised of kokanee experts from around the Pacific Northwest and Canada.

There is an immediate need to obtain better data on the abundance and distribution of remaining kokanee stocks in the Lake Washington and Lake Sammamish drainages. This will require comprehensive and long-term surveys of kokanee in the Sammamish River / Lake Sammamish drainage. In addition, more information is needed on the distribution, population and ecology of kokanee in Lake Sammamish to better understand if kokanee populations are declining because of population “bottlenecks” in the lake environment, the stream environment, or both.

A comprehensive genetics analysis of the kokanee subpopulations present in tributaries to the Sammamish River and Lake Sammamish is needed to determine which are of native, non-native, or mixed stock origin. Over the last two years genetic samples from 33 kokanee have been obtained in the Lake Sammamish drainage. These are awaiting analysis at the genetics lab at NMFS. There is some evidence based upon field observations of size and coloration that native kokanee may be present in low numbers in some Sammamish River tributaries, including

Issaquah Creek. Genetic sampling should also be conducted to determine if any native kokanee remain in the Big Bear Creek drainage, and to determine the lineage of kokanee in Walsh Lake.

It will be important for conservation of native kokanee in the Sammamish River / Lake Sammamish drainage to identify any remaining subpopulations possessing native-origin fish. At this time, the most likely source of a native broodstock is early-run kokanee in Issaquah Creek. Based upon observations of early spawning timing, other remnant populations of native kokanee may be present in Sammamish River tributaries (Ostergaard et al. 1995), and in the Walsh Lake system. Finally, there is a possible remnant population of kokanee originating from Big Bear Creek in Lake Stevens in Snohomish County. Big Bear Creek kokanee fry originating from the WDG egg taking station at the confluence of Evans Creek were outplanted to a number of systems, including Lake Stevens. WDG biologists observed noticeable differences in the appearance of a number of kokanee from Lake Stevens from fish originating from Lake Whatcom, suggesting that the former were derived from native Big Bear Creek stocks (Fletcher 1973a).

Efforts to ensure the sustainability of native kokanee have the highest chance for success if the ecology of the streams, rivers, and lakes within which salmon reside is understood, and the unique qualities and resource requirements of the salmon stock to be conserved are known (Miller et. al. 1990). Those factors limiting natural production must first be identified. This is not an easy task, since a number of factors may limit kokanee populations in combination. Certain factors such as zooplankton densities may severely limit kokanee production during some years, but may have little affect on survival in other years (Thiesfeld et al. 1999). Compensatory mortality caused by interspecific and intraspecific competition may result in higher-than-expected adult returns in some systems. The factors which can potentially limit kokanee production include access of adult spawners to spawning areas, the availability of clean spawning gravels, access of juvenile fish from tributaries to lakes, juvenile survival and growth in the lake environment, and size and fecundity of adults.

Many studies conducted to date suggest that food limitations in lakes and reservoirs (i.e., zooplankton densities, particularly that of *Daphnia*) may be the most important factor constraining kokanee populations (Paragamian and Bowles 1995). Additional zooplankton studies are to be started in Lake Sammamish in 2000. Under these conditions, management measures which improve the availability of cladocerans (e.g., *Daphnia*) and other preferred forage zooplankton species to juvenile kokanee in lakes may be warranted. The use of a hatchery stocking program to increase natural production may only provide short-term benefits when juvenile kokanee densities may be naturally constrained by food production in the lake environment. Other studies suggest that food may not be a limiting factor to juvenile kokanee during some years, and that predation by other fish species may be the greatest source of mortality to these fish (Beaucamp et al. 1995; Thiesfeld et al. 1999).

WDFW (Pfeifer 1999) has identified a number of specific studies needed to better understand the life history, ecology, and limiting factors of kokanee in the Lake Sammamish drainage. These studies include:

- Document the abundance, distribution, periodicity, and physico-chemical relationships of zooplankton in Lake Sammamish;
- Estimate the abundance of predators, and assess the effects of predation on kokanee;
- Determine the abundance of sockeye and kokanee using trawl and hydroacoustic techniques;
- Evaluate the impacts of sockeye salmon (e.g., competition for shared food resources) on kokanee populations;
- Determine the distribution and movements of kokanee relative to limnological and physical habitat conditions;
- Monitor fry survival of kokanee;
- Assess spawning and rearing conditions for kokanee in Lake Sammamish Tributaries, including Issaquah Creek;
- Evaluate the feasibility of supplementation programs to improve native kokanee stocks, including culturing fish at the Issaquah Hatchery.

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Appendix A: Regulatory Status of *Oncorhynchus nerka* Populations in the Lake Washington Watershed

In response to a petition to protect Baker Lake sockeye salmon under the Endangered Species Act (ESA) in September 1994, the National Marine Fisheries Service (NMFS) conducted a status review of sockeye salmon in Washington and Oregon. The findings of this status review were released in December 1997 (Gustafson et al. 1997). The sockeye salmon Biological Review Team (BRT) identified six sockeye salmon Evolutionarily Significant Units (ESUs) in Washington, including the Okanogan River, Lake Wenatchee, Quinault Lake, Ozette Lake, Baker River, and Lake Pleasant.

Within the Lake Washington and Lake Sammamish basins, only sockeye salmon in the Big Bear Creek drainage were identified for consideration under the ESA (Gustafson et al. 1997). The Big Bear Creek ESU includes sockeye salmon and kokanee that spawn in Big Bear Creek and two of its tributaries, Cottage Lake Creek and Evans Creek. NMFS defined this as a "provisional" ESU because of uncertainties regarding the genetic origin of sockeye salmon and kokanee within this drainage. Sockeye originating from the Baker Lake system were outplanted within this basin beginning in the 1930s, while kokanee from Lake Whatcom and other basins (unknown origin) were outplanted beginning in the late 1910s (Pfeifer 1992). NMFS stated that any "kokanee-sized" *O. nerka* identified as residual or resident sockeye salmon in Big Bear Creek would be considered part of the provisional sockeye salmon ESU (Gustafson et al. 1997). NMFS concluded that the Big Bear Creek provisional ESU was not presently in danger of extinction, nor was it likely to become endangered in the foreseeable future. For this reason, the listing of sockeye salmon within this provisional ESU under the ESA was not found to be warranted.

Based upon historical records, stocking histories, and genetic data, NMFS concluded that sockeye salmon in the Cedar River, Issaquah Creek, and lakeshore spawners in Lake Washington and Lake Sammamish were derived from hatchery transplants originating outside of the basin. Consequently, sockeye in these drainages were not considered as part of any ESU, and therefore were not subject to consideration and eventual protection under the ESA (Gustafson et al. 1997).

The 1992 Salmon and Steelhead Inventory (SASI) prepared for the Puget Sound (WDFW et al. 1994) identified three separate stocks of sockeye salmon in the Lake Washington basin. These are: (1) Cedar River sockeye, which are considered non-native in origin; (2) Lake Washington and Lake Sammamish tributaries, which are a mixed stock of non-native and native origin; and (3) Lake Washington lakeshore spawners, which are considered of unknown origin.

In 1998, King County submitted a letter to the U.S. Fish and Wildlife Service (USFWS) expressing concern over dwindling numbers of kokanee in the Lake Sammamish Basin (Sims 1998). The USFWS has authority in listing resident fish species under the ESA, including kokanee. At this time, a status review of kokanee in the Sammamish River / Lake Sammamish basins has not yet been conducted by the USFWS. Consequently, no actions have been taken to list kokanee in this drainage.

Appendix B: WDFW's Proposed Recovery Plan Options

WDFW has identified a number of potential limiting factors to kokanee in the Lake Sammamish subbasin (Pfeifer 1995). These include: 1) blockages to upstream passage caused by barriers and reaches with inadequate water depths; 2) redd overposition by other salmon species; 3) water quality conditions in Lake Sammamish and its tributaries; 4) predation and poaching; 5) stock collapse due to low numbers; 6) displacement by anadromous sockeye; and 7) competition for food (zooplankton) with other fish species. Pfeifer (1995) noted that very little is known about the life history or survival between life stages of native kokanee in the Lake Sammamish subbasin.

Based upon existing information, the WDFW has developed three alternative stock recovery plan options for early-run (i.e., late summer) kokanee in the Lake Sammamish drainage (Pfeifer 1999). All three stock recovery plan options assume the use of the Issaquah Creek hatchery to supplement existing runs of wild/native kokanee in the Lake Sammamish subbasin during the first years of the program. Streamside incubators would be used in addition to the hatchery during subsequent years for fry production (Pfeifer 1999). The three stock recovery alternatives are:

- *Stock Recovery Option A.* Use of early-entry Issaquah Creek stock alone for stock recovery. The main advantage to this alternative is that it would not involve additional introductions of exotic stocks. This is the preferred recovery option by WDFW.

- *Stock Recovery Option B.* Replacement/restoration of kokanee population using an outside, exotic stock only. Kokanee from Kootenay Lake, British Columbia, have been proposed as a suitable broodstock because they have a similar spawning timing to early-run Issaquah Creek kokanee.

- *Stock Recovery Option AB.* A combination of Recovery Options A and B